Colorado Wind Workshop

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Denver, CO

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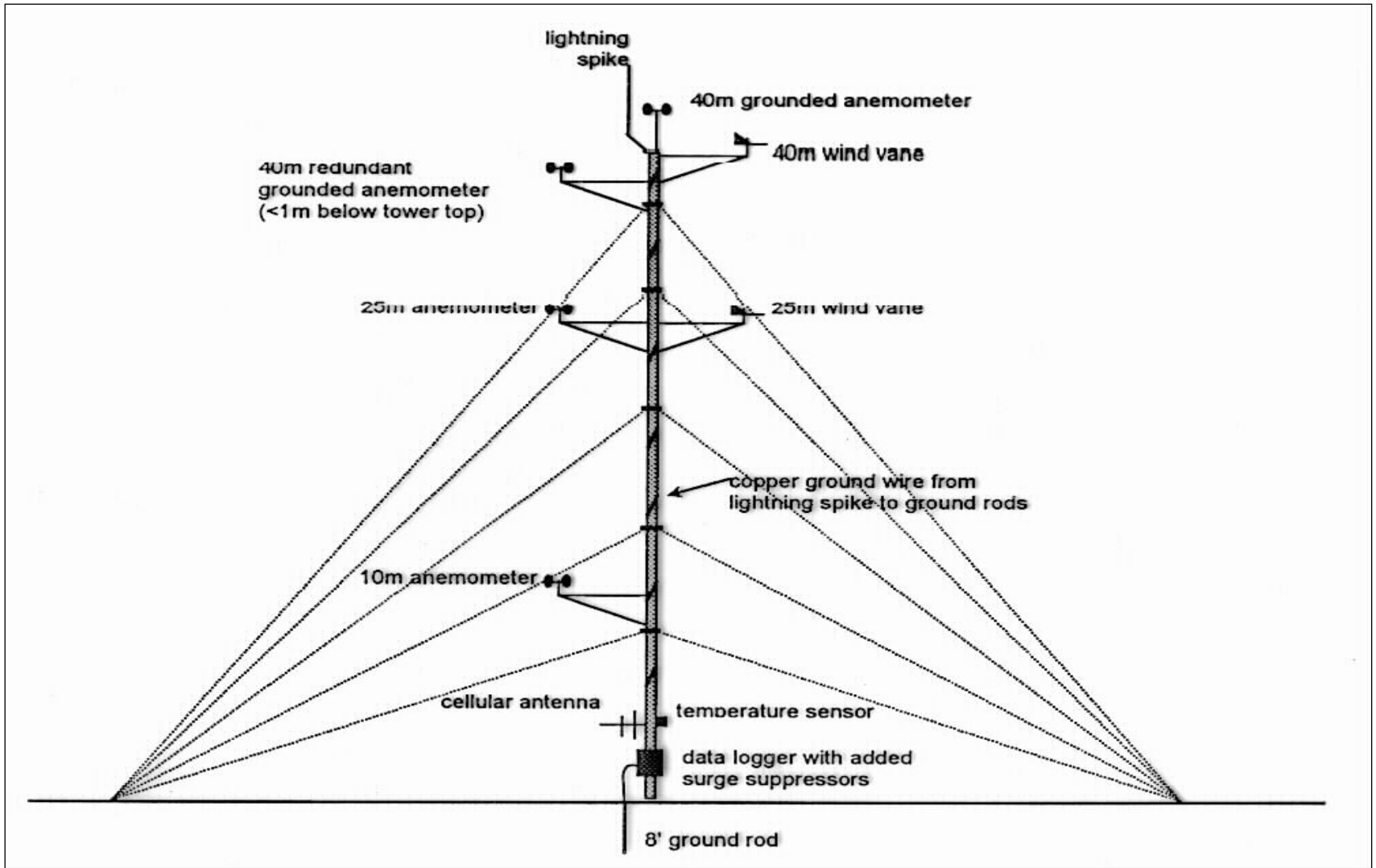
Overview

- Utah's Anemometer Loan Program
- How to:
  - Site an Anemometer
  - Install an Anemometer
  - Collect and Interpret Data

The Story

- Wind Repeats Itself
- Anemometer Loan Program
  - Over 250 calls
  - Anememometer?…What is it?
  - 50 Applicants
  - 10 anemometers became 15 anemometers

Equipment Configuration

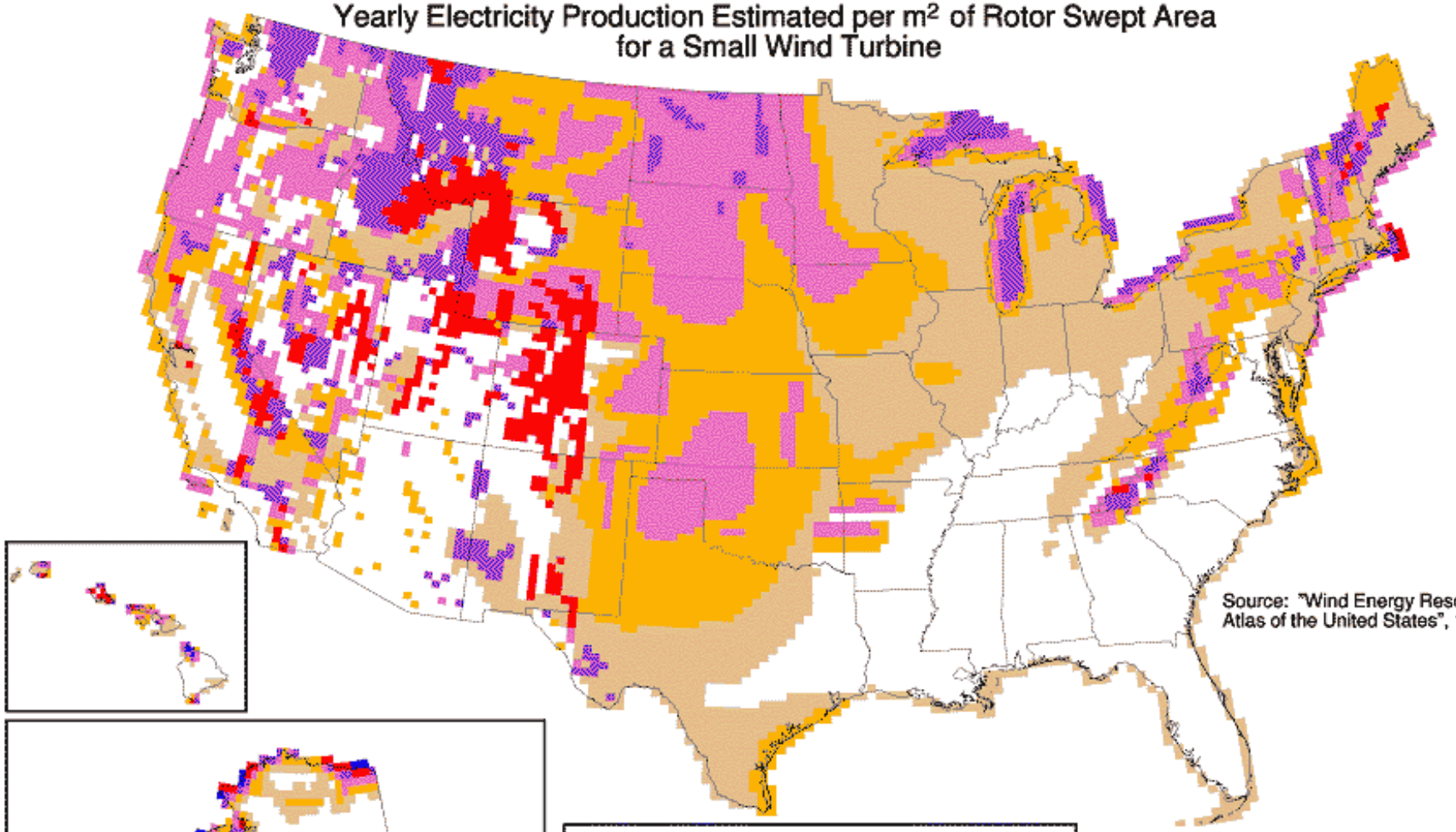


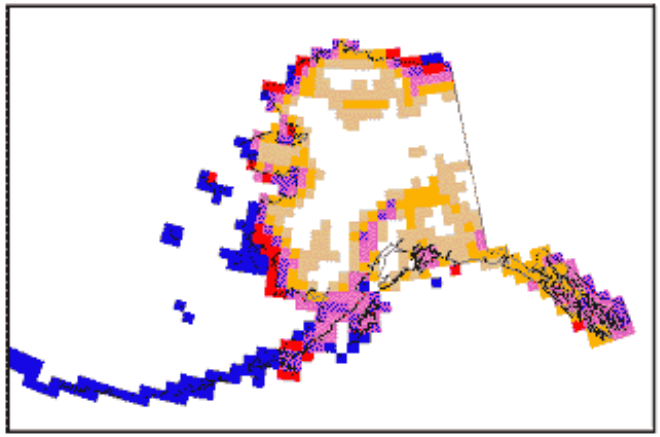
Siting: Macro

- Review Wind Maps:
  - NREL: www.nrel.gov/wind/database.html
- Obtain Historical Wind Data:
  - Airports, Department of Transportation
- Analyze Topograhpic Maps

United States - Wind Resource Map

Yearly Electricity Production Estimated per m^2 of Rotor Swept Area for a Small Wind Turbine





Source: "Wind Energy Resource Atlas of the United States", 1987

Small Wind Turbine Productivity Estimates*

Wind Power Class	Productivity per m^2 of swept area** (kWh/year)	Wind Power Density at 33 ft (10 m) (W/m^2)	Wind Speed at 33 ft (10 m) (mph)	Wind Speed at 33 ft (10 m) (m/s)
1	< 350	<100	< 9.8	< 4.4
2	350 - 500	100 - 150	9.8 - 11.5	4.4 - 5.1
3	500 - 610	150 - 200	11.5 - 12.5	5.1 - 5.6
4	610 - 690	200 - 250	12.5 - 13.4	5.6 - 6.0
5	690 - 770	250 - 300	13.4 - 14.3	6.0 - 6.4
6	770 - 880	300 - 400	14.3 - 15.7	6.4 - 7.0
7	880 -1170	400 -1000	15.7 - 21.1	7.0 - 9.4

* Estimates are based on different models and sizes of wind turbines assuming a tower height of 80 ft (24 m).

** For systems of different sizes, multiply the estimated productivity by the total swept area of the turbine.

U.S. Department of Energy
National Renewable Energy Laboratory

NREL

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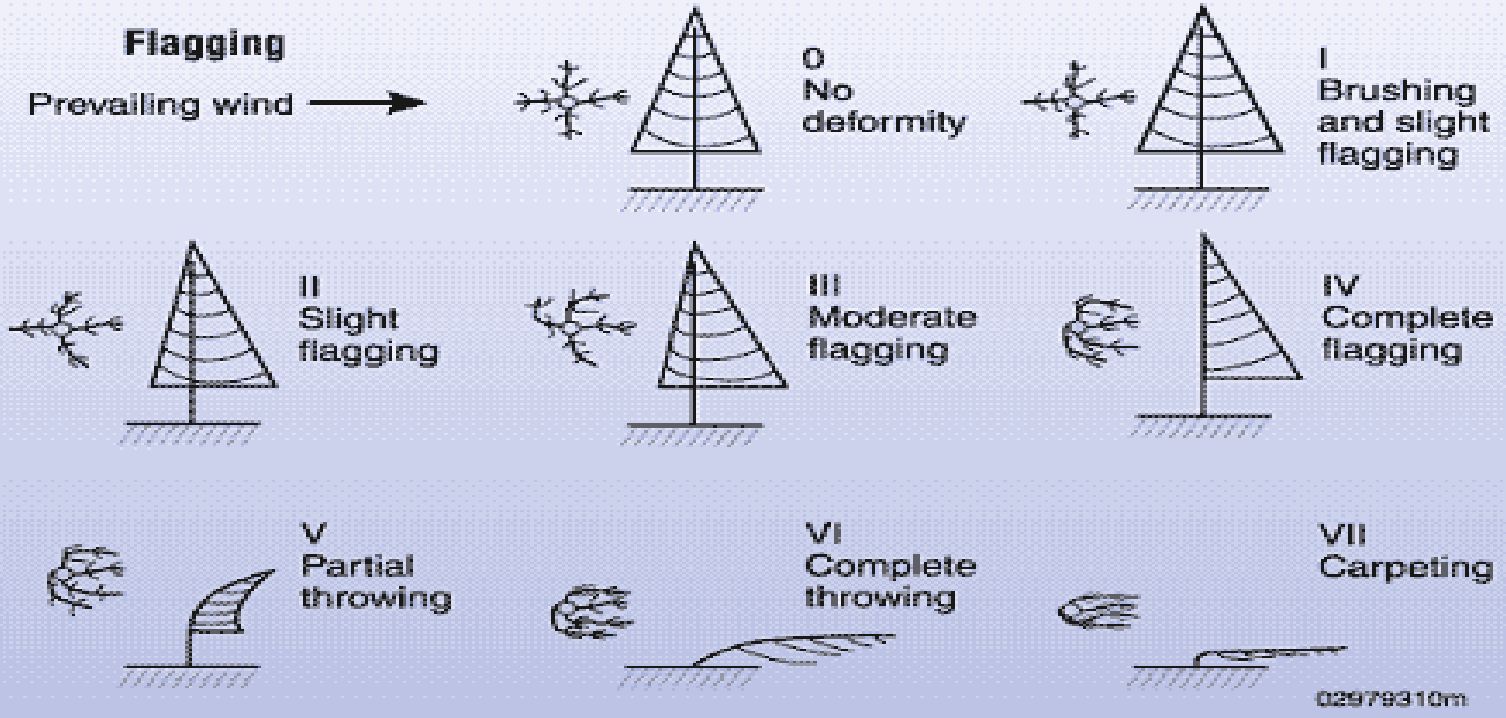
Siting: Micro

- Visually observe site vegetation
- Legal Issues
- Building codes and covenants
- Environmental Issues

Siting: Wind Deformation



Griggs-Putnam Index of Deformity

Index	I	II	III	IV	V	VI	VII
Wind mph	7-9	9-11	11-13	13-16	15-18	16-21	22+
Speed m/s	3-4	4-5	5-6	6-7	7-8	8-9	10

Siting: Micro

Legal Issues

- City, town, or county ordinances
  - Restricting height or
  - Requiring minimum setbacks
- Conditional use permit vs. Cell tower

Environmental Issues

- **Neighbors' concerns**
  - Visual impact
  - Noise
- **Potential physical** obstacles
  - Growing trees
  - Planned Construction
  - Terrain has major impact on wind resource

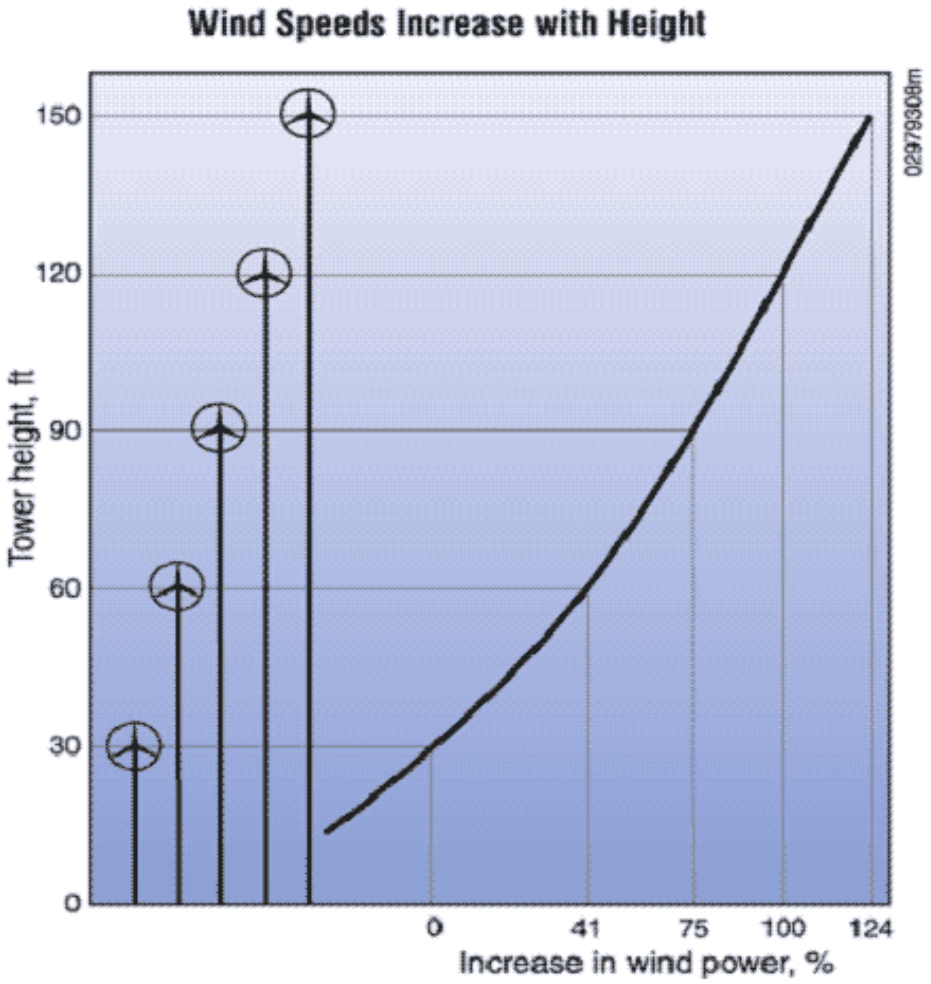
Utah Anemometer Loan Program

How we Choose our Recipients

- Applicants into Categories
  - Farm/Irrigator
  - Off-grid
  - Business
  - Large Scale
  - Homeowner
- Topographical Maps
- Pictures from applicants
- Application

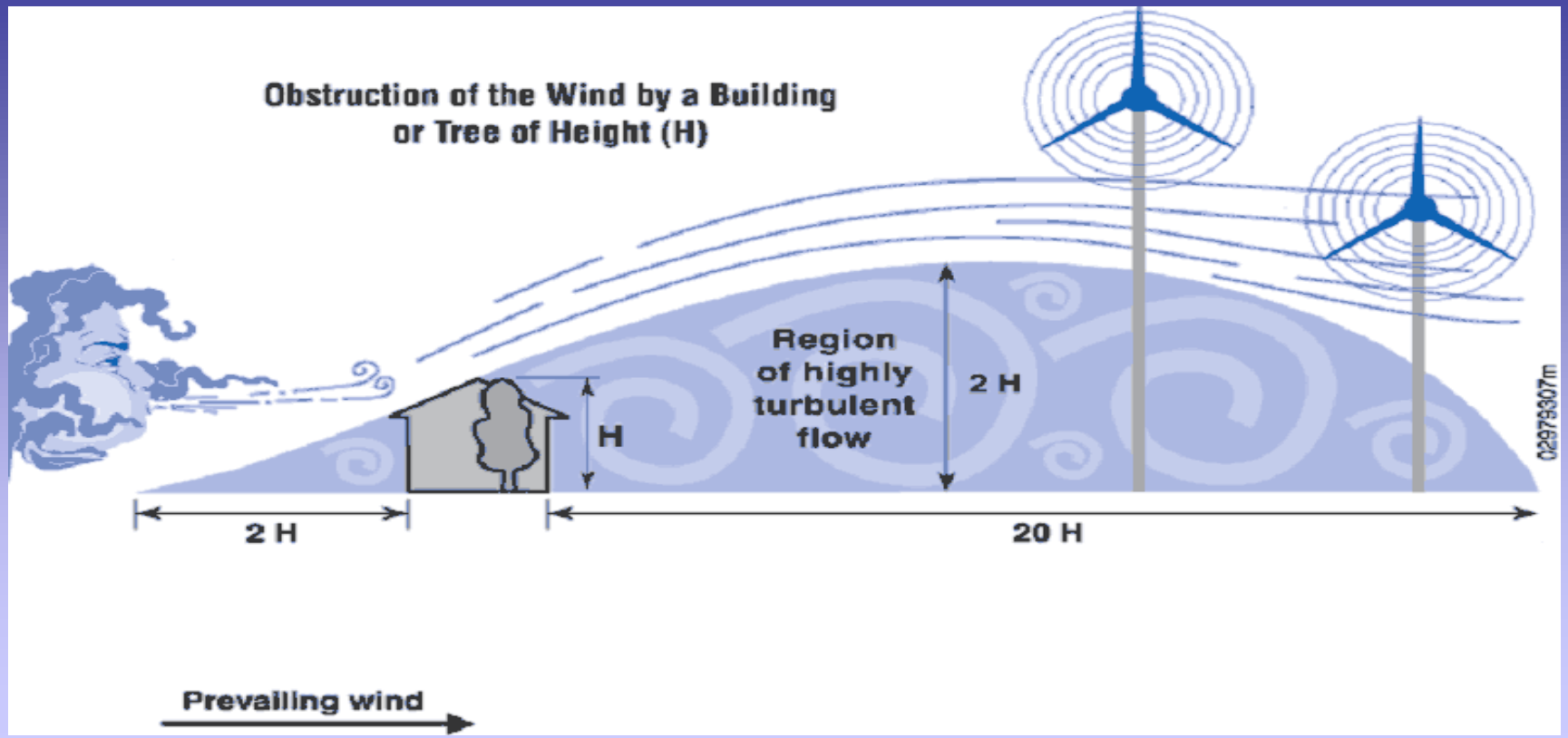
Installation of Tower

- Tower height matters: wind speed increases exponentially with height.
- Small increases in wind speed result in large increases in power
- Tall towers often needed for clearance above obstacles *(turbulence)*
- May require a variance or a special use permit



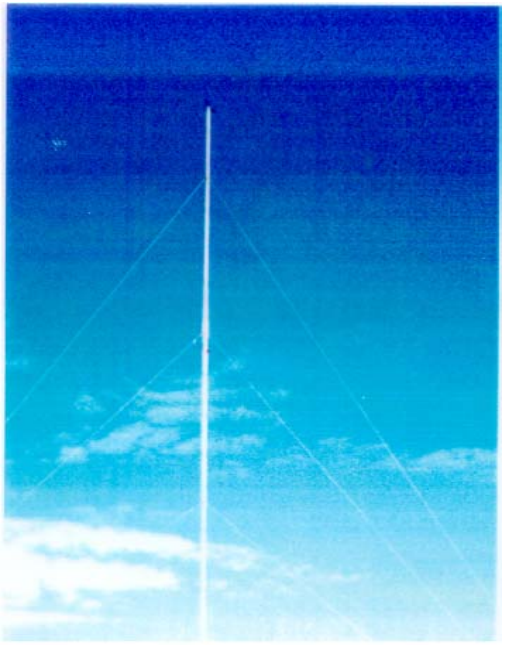
Installation of Tower

Height or Distance Needed



Installation of Tower

- 20-M Tower ~ 66 feet
  - –Use free standing tower, do not mount on buildings
  - –Winch: powered by car battery
  - –Gin Pole
  - –Anchors: depending on soil type
- Choose areas secure from vandalism or animal damage



How to Collect and Interpret Data

- Establish project objectives
  - –Duation: at least one year
- Develop data collection plan
  - –Choose reliable, proven, and easily maintained wind equipment
  - –Record hourly, wind speed, direction, and turbulence (optional temperature—I recommend temperature)

Data Analysis

- For a minimum analysis, evaluate:
  - Monthly average wind speed
  - Annual wind speed frequency distribution
  - Inter-annual variations, if possible
  - Energy production estimates (including losses)
- For a more comprehensive analysis, also include:
  - Joint speed and direction frequency distribution
  - Wind shear
  - Diurnal variations
  - Turbulence intensity

Data Analysis

- After 4-6 months of monitoring, evaluate sites for continuation, relocation, or termination by comparing to long-term reference sites (if available)
- Continue monitoring program 12-24 months and select most appropriate sites for long-term reference purposes
- Evaluate data and proceed to site-specific evaluations, if warranted

Data Processing and Quality Control

- Process the data at least monthly
- Identify irregularities in data (unreasonable values of speed or direction)
- Compare to nearby sites for agreement and continuity
- Implement corrective action promptly

Data Quality Checking

- Identify events that may affect data quality
- Identify periods of missing data
- Identify data anomalies (through validations tests)
- Remove erroneous data values and document changes
- Maintain a log of data collected and the results of quality checking

Lessons Learned

- Anemometers should be located where they represent conditions to be experienced by turbines
- High quality data essential to accurate resource assessment
  - High quality equipment
  - Trained personnel—don't site anemometer next to tree
  - Frequent data quality checking—detect freezing
  - Thorough data analysis
- There is no substitute for long-term (one year or more) on-site data


It’s Just the Beginning…